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(54) **METHOD FOR THE PRODUCTION OF ERYTHROPOIETIN**

HERSTELLUNGSVERFAHREN FÜR ERYTHROPOIETIN  
METHODE DE PRODUCTION DE L'ERYTHROPOETINE

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(56) References cited:  
EP-A-0 148 605  
US-A-4 377 513

**Description**

**FIELD OF THE INVENTION**

[0001] The present invention is directed to the expression of the DNA of Claim 1 and to the *in vitro* production of active human erythropoietin.

**BACKGROUND OF THE INVENTION**

[0002] Erythropoietin (hereinafter EPO) is a circulating glycoprotein, which stimulates erythrocyte formation in higher organisms. See, Carnot et al., *Compt. Rend.*, 143:384 (1906). As such, EPO is sometimes referred to as an erythropoietic stimulating factor.

[0003] The life of human erythrocytes is about 120 days. Thus, about 1/120 of the total erythrocytes are destroyed daily in the reticulo-endothelial system. Concurrently, a relatively constant number of erythrocytes are produced daily to maintain the level of erythrocytes at all times (Guyton, *Textbook of Medical Physiology*, pp 56-60, W. B. Saunders Co., Philadelphia (1976)).

[0004] Erythrocytes are produced by the maturation and differentiation of the erythroblasts in bone marrow, and EPO is a factor which acts on less differentiated cells and induces their differentiation to erythrocytes (Guyton, *supra*). [0005] EPO is a promising therapeutic agent for the clinical treatment of anemia or, in particular, renal anemia. Unfortunately, the use of EPO is not yet common in practical therapy due to its low availability.

[0006] For EPO to be used as a therapeutic agent, consideration should be given to possible antigenicity problems, and it is therefore preferable that EPO be prepared from a raw material of human origin. For example, human blood or urine from patients suffering from aplastic anemia or like diseases who excrete large amounts of EPO may be employed. These raw materials however, are in limited supply. See, for example, White et al., *Res. Prog. Horm. Res.*, 24:459 (1972) and Gordon, *Vitam. Horm. (N.Y.)* 31:105 (1973), the disclosures of which are incorporated herein by reference.

[0007] The preparation of EPO products has generally been via the concentration and purification of urine from patients exhibiting high EPO levels, such as those suffering from aplastic anemia and like diseases. See for example, U.S. Patent Nos. 4,397,840; 4,303,650 and 3,865,801 the disclosures of which are incorporated herein by reference. The limited supply of such urine is an obstacle to the practical use of EPO, and thus it is highly desirable to prepare EPO products from the urine of healthy humans. A problem in the use of urine from healthy humans is the low content of EPO therein in comparison with that from anemic patients. In addition, the urine of healthy individuals contains certain inhibiting factors which act against erythropoiesis in sufficiently high concentration so that a satisfactory therapeutic effect would be obtained from EPO derived therefrom only following significant purification.

[0008] EPO can also be recovered from sheep blood plasma, and the separation of EPO from such blood plasma has provided satisfactorily potent and stable water-soluble preparations. See, Goldwasser, *Control Cellular Dif. Develop.*, Part A, pp 487-494, Alan R. Liss, Inc., N.Y. (1981), which is incorporated herein by reference. Sheep EPO would, however, be expected to be antigenic in humans.

[0009] Thus, while EPO is a desirable therapeutic agent, conventional isolation and purification techniques, used with natural supply sources, are inadequate for the mass production of this compound.

[0010] Sugimoto et al., in U.S. Patent No. 4,377,513 describe one method for the mass production of EPO comprising the *in vitro* multiplication of human lymphoblastoid cells, including Namalwa, BALL-1, NALL-1 TALL-1 and JBL.

[0011] The reported production by others of EPO using genetic engineering techniques had appeared in the trade literature. However, neither an enabling disclosure nor the chemical nature of the product has yet been published. In contrast, the present application provides an enabling disclosure for the mass production of proteins displaying the biological properties of proteins displaying the biological properties of human EPO. It is also possible by such techniques to produce proteins which may chemically differ from authentic human EPO, yet manifest similar (and in some cases improved) properties. For convenience all such proteins displaying the biological properties of human EPO may be referred to hereinafter as EPO whether or not chemically identical thereto.

**SUMMARY OF THE INVENTION**

[0012] The present invention is directed to the expression of the DNA of claim 1 that expresses surprisingly high levels of human EPO, and the mass production *in vitro* of active human EPO therefrom. Described also are suitable expression vectors for the production of EPO, expression cells, purification schemes and related processes.

[0013] As described in greater detail *infra*, EPO was obtained in partially purified form and was further purified to homogeneity and digested with trypsin to generate specific fragments. These fragments were purified and sequenced. EPO oligonucleotides were designed based on these sequences and synthesized. These oligos were used to screen a

human genomic library from which was isolated an EPO gene.

[0014] The EPO gene was verified on the basis of its DNA sequence which matched many of the tryptic protein fragments sequenced. A piece of the genomic clone was then used to demonstrate by hybridization that EPO mRNA could be detected in human fetal (20 weeks old) mRNA. A human fetal liver cDNA library was prepared and screened. Three EPO cDNA clones were obtained (after screening >750,000 recombinants). Two of these clones were determined to be full length as judged by complete coding sequence and substantial 5'-prime and 3'-prime untranslated sequence. These cDNAs have been expressed in both SV40 virus transformed monkey cells (the COS-1 cell line; Gluzman, *Cell* 23:175-182 (1981)) and Chinese hamster ovary cells (the CHO cell line; Urlaub, G. and Chasin, L. A. *Proc. Natl. Acad. Sci. USA* 77:4216-4280 (1980)). The EPO produced from COS cells is biologically active EPO *in vitro* and *in vivo*. The EPO produced from CHO cells is also biologically active *in vitro* and *in vivo*.

[0015] The EPO cDNA clone has an interesting open reading frame of 14-15 amino acids (aa) with initiator and terminator from 20 to 30 nucleotides (nt) upstream of the coding region. A representative sample of *E. coli* transfected with the cloned EPO gene has been deposited with the American Type Culture Collection, Rockville, Maryland, where it is available under Accession Number ATCC 40153.

## BRIEF DESCRIPTION OF DRAWINGS AND TABLES

[0016]

Table 1 is the base sequence of an 87 base pair exon of a human EPO gene;

Figure 1 illustrates the detection of EPO mRNA in human fetal liver mRNA;

Table 2 illustrates the amino acid sequence of an EPO protein deduced from the nucleotide sequence of lambda-HEPOFL13;

Table 3 illustrates the nucleotide sequence of the EPO cDNA in lambda-HEPOFL13 (shown schematically in Figure 2) and the amino acid sequence deduced therefrom;

Figure 3 illustrates the relative positions of DNA inserts of four independent human EPO genomic clones;

Figure 4 illustrates a map of the apparent intron and exon structure of the human EPO gene;

Table 4 illustrates a DNA sequence of the EPO gene;

Figures 5A, 5B and 5C illustrate the construction of the vector 91023(B);

Figure 6 illustrates SDS polyacrylamide gel analysis of EPO produced in COS-1 cells compared with native EPO;

Table 5 illustrates the nucleotide and amino acid sequence of the EPO clone, lambda-HEPOFL6;

Table 6 illustrates the nucleotide and amino acid sequence of the EPO clone, lambda-HEPOFL8;

Table 7 illustrates the nucleotide and amino acid sequence of the EPO clone lambda-HEPOFL13;

Figure 7 is a schematic illustration of the plasmid pRK1-4; and

Figure 8 is a schematic illustration of the plasmid pOBPV-MMT neo(342-12).

## DETAILED DESCRIPTION

[0017] The present invention is directed to the production of EPO by the *in vitro* expression of the DNA of claim 1.

[0018] The patent and scientific literature is replete with processes reportedly useful for the production of recombinant products. Generally, these techniques involve the isolation or synthesis of a desired gene sequence, and the expression of that sequence in either a prokaryotic or eucaryotic cell, using techniques commonly available to the skilled artisan. Once a given gene has been isolated, purified and inserted into a transfer vector (i.e., cloned), its availability in substantial quantity is assured. The vector with its cloned gene is transferred to a suitable microorganism or cell line, for example, bacteria, yeast, mammalian cells such as, COS-1 (monkey kidney), CHO (Chinese hamster ovary), insect cell lines, and the like, wherein the vector replicates as the microorganism or cell line proliferates and from which the vector can be isolated by conventional means. Thus there is provided a continuously renewable source of the gene for further manipulations, modifications and transfers to other vectors or other loci within the same vector.

[0019] Expression may often be obtained by transferring the cloned gene, in proper orientation and reading frame, into an appropriate site in a transfer vector such that translational read-through from a prokaryotic or eucaryotic gene results in synthesis of a protein precursor comprising the amino acid sequence coded by the cloned gene linked to Met or an amino-terminal sequence from the prokaryotic or eucaryotic gene. In other cases, the signals for transcription and translation initiation can be supplied by a suitable genomic fragment of the cloned gene. A variety of specific protein cleavage techniques may be used to cleave the protein precursor, if produced, at a desired point so as to release the desired amino acid sequence, which may then be purified by conventional means. In some cases, the protein containing the desired amino acid sequence is produced without the need for specific cleavage techniques and may also be released from the cells into the extracellular growth medium.

## Isolation of a Genomic Clone of Human EPO

[0020] Human EPO was purified to homogeneity from the urine of patients afflicted with aplastic anemia as described *infra*. Complete digestion of this purified EPO with the protease trypsin, yielded fragments which were separated by reverse phase high performance liquid chromatography, recovered from gradient fractions, and subjected to microsequence analysis. The sequences of the tryptic fragments are undetermined in Tables 2 and 3 and are discussed in more detail *infra*. Two of the amino acid sequences, Val-Asn-Phe-Tyr-Ala-Tyr-Lys and Val-Tyr-Ser-Asn-Phe-Lau-Arg, were chosen for the design of oligonucleotide probes (resulting in an oligonucleotide pool 17nt long and 32-fold degenerate, and an oligonucleotide pool 18nt long and 128-fold degenerate, from the former tryptic fragment, as well as two pools 14nt long, each 49-fold degenerate, from the latter tryptic fragment, respectively). The 32-fold degenerate 17mer pool was used to screen a human genomic DNA library in a  $\chi$ 44 vector (22) using a modification of the Woo and O'Malley *in situ* amplification procedure (47) to prepare the filters for screening.

[0021] As used herein, arabic numbers in parentheses, (1) through (61), are used to refer to publications that are listed in numerical order at the end of this specification.

[0022] Phage hybridizing to the 17mer were picked, pooled in small groups and probed with the 14mer and 18mer pools. Phage hybridizing to the 17mer, 18mer and 14mer pools were plaque purified and fragments were subcloned into M13 vectors for sequencing by the dideoxy chain termination method of



[illegible]

TABLE 2 (CONT.)

[illegible]

TABLE 3

[illegible]

DNA sequence indicated that the 17mer hybridizing region was contained within an 87bp exon, bounded by potential splice acceptor and donor sites.

**[0023]** Positive confirmation that these two clones (designated herein, lambda-HEPO1 and lambda-HEPO2) are HEPO genomic clones has been obtained by sequencing additional exons containing other tryptic fragment coding information.

### Isolation of EPO cDNA Clones

**00024** Northern Analysis (56) of human fetal (20 weeks old) liver mRNA was conducted using a 95nt single-stranded probe prepared from an M13 clone containing a portion of the 87bp exon described in Table 1. As illustrated in Figure 1, a strong signal could be detected in fetal liver mRNA. The precise identification of this band as EPO mRNA was achieved by using the same probe to screen a bacteriophage lambda cDNA library of the fetal liver mRNA (25). Several hybridizing clones were obtained at a frequency of approximately 1 positive per 250,000 recombinants and screened. The complete nucleotide and deduced amino acid sequences for these clones (lambda-HEPOFL13 and lambda-HEPOFL8) are shown in Tables 7 and 6. The EPO coding information is contained within 594nt in the 5-prime half of the cDNA, including a very hydrophobic 27 amino acid leader and the 168 amino acid mature protein.

**[0025]** The identification of the N-terminus of the mature protein was based on the N-terminal sequence of the protein secreted in the urine of persons with aplastic anemia as illustrated herein (Table 1), and as published by Goldwasser (26), Sue and Sytkowski (27), and by Yangawa (21). Whether this N-terminus (Ala-Pro-Arg-) represents the actual N-terminus found on EPO in circulation or whether some cleavage occurs in the kidney or urine is presently unknown.

[0026] The amino acid sequences which are underlined in Tables 2 and 3 indicate those tryptic fragments or the portion of the N-terminus for which protein sequence information was obtained. The deduced amino acid sequence agrees precisely with the tryptic fragments which have been sequenced, confirming that the isolated gene encodes human EPO.

# Structure and Sequence of the Human EPO Gene

**000271** The relative positions of the DNA inserts of four independent human EPO genomic clones are shown in Figure 1. Hybridization analysis of these cloned DNAs with oligonucleotide probes and with various probes prepared from the two classes of EPO cDNA clones positioned the EPO gene within the approximately 3.3 kb region shown by the dashed line in Figure 3. Complete sequence analysis of this region (see Example 4) and comparison with the cDNA database resulted in the map of the intron and exon structure of the EPO gene shown in Figure 4. The EPO gene is divided into 5 exons. Part I and IV, and part of exon V, contain the protein coding information. The remainder of exons I and V encode the 5-prime and the 3-prime untranslated sequences respectively.

### Transient Expression of EPO in COS Cells

**[0028]** To demonstrate that biologically active EPO could be expressed in an *in vitro* cell culture system, COS cell expression studies were conducted (58). The vector used for the transient studies, p81023(B), is described in Example 5. This vector contains the adenovirus major late promoter, an SV40 polyadenylation sequence, an SV40 origin of replication, SV40 enhancer, and the adenovirus VA gene. The cDNA insert in lambdaBIOEPOFL13 (see Table 6) was inserted into the p81023(B) vector, downstream of the adenovirus major late promoter. This new vector is identified as pPTFL13.

**[0029]** Twenty-four hours after transfection of this construct into the M6 strain of COS-1 cells (Horowitz et al., *J. Mol. Biol.* 147:147-149 (1983)), the cells were washed, changed to serum free media, and the cells were harvested 48 hours later. The level of release of EPO into the culture supernatant was then examined, using a quantitative radioimmunoassay for EPO (55). As shown in Table 8, (Example 6) immunologically reactive EPO was expressed. The biological activity of the EPO produced from LPO-13 was also examined. In a separate experiment, the vector containing EPO cDNA from lambda-HEPOFL3 was transfected into COS-1 cells and media harvested as described supra. EPO in the media was then quantified by the either of two *in vitro* biological assays, <sup>3</sup>H-thymidine and CFU-E (12, 28), and by either of two *in vivo* assays, hypoxic mouse and stained rat (30, 31) (see Table 9, Example 7). These results demonstrate that the biologically active EPO is produced in COS-1 cells. By Western blotting, using a polyclonal anti-EPO antibody, the EPO produced by COS cells has a mobility on SDS-polyacrylamide gels which is identical to that of native EPO prepared from human urine (Example 8). Thus, the extent of glycosylation of COS-1 produced EPO may be similar to that of native EPO.

[0030] Different vectors containing other promoters can also be used in COS cells or in other mammalian or eukaryotic cells. Examples of such other promoters useful in the practice of this invention include SV40 early and late

promoters, the mouse metallothionein gene promoter, the promoter found in the long terminal repeats of avian or mammalian retroviruses, the baculovirus polyhedron gene promoter and others. Examples of other cell types useful in the practice of this invention include E. coli, yeast, mammalian cells such as CHO (Chinese hamster ovary), C127 (monkey epithelium), 3T3 (mouse fibroblast) CV-1 (African green monkey kidney), and the insect cells such as those from *Spartanella fusca* and *Drosophila melanogaster*. These alternate promoters and/or cell types may enable regulation of the timing or level of EPO expression, producing a cell-specific type of EPO, or the growth of large quantities of EPO producing cells under less expensive, more easily controlled conditions.

[0031] An expression system which retains the benefits of mammalian expression but requires less time to produce a high-level expression cell line is composed of an insect cell line and a DNA virus which reproduces in this cell line. The virus is a nuclear polyhedrosis virus. It has a double-stranded circular DNA genome of 128 kb. The nucleocapsid is rod-shaped and found packaged in two forms, the non-occluded form, a membrane budded virus and an occluded form, packaged in a protein crystal in the infected cell nucleus. These viruses can be routinely propagated in *in vitro* insect cell culture and are amenable to all routine animal virological methods. The cell culture media is typically a nutrient cell solution and 10% fetal calf serum.

[0032] *In vitro*, virus growth is initiated when a non-occluded virus (NOV) enters a cell and moves to the nucleus where it replicates. Replication is nuclear. During the initial phase (8-18 hrs. post-infection) of viral application, nucleocapsids are assembled in the nucleus and subsequently bud through the plasma membrane as NOVs, spreading the infection through the cell culture. In addition, some of the nucleocapsids subsequently (18+ hrs. post-infection) remain in the nucleus and are occluded in a protein matrix, known as the polyhedral inclusion body (PIB). This form is not infectious in cell culture. The matrix is composed of a protein known as polyhedrin, MW 33 kd. Each PIB is approximately 1 mm in diameter, and there can be as many as 100 PIBs per nucleus. There is clearly a great deal of polyhedrin produced late in the infection cycle, as much as 25% of total cellular protein.

[0033] Because the PIB plays no role in the *in vitro* replication cycle, the polyhedrin gene can be deleted from the virus chromosome with no effect on *in vitro* viability. In using the virus as an expression vector, we have replaced the polyhedrin gene coding region with the foreign DNA to be expressed, placing it under the control of the polyhedrin promoter. This results in a non-PIB forming virus phenotype.

[0034] This system has been utilized by several researchers the most noted being Pennock et al. and Smith et al. Pennock et al. (Gregory D. Pennock, Charles Shoemaker, and Lois K. Miller, *Molecular and Cell Biology* 3:84, p. 399-406) have reported on the high level expression of a bacterial protein,  $\beta$ -galactosidase, when placed under the control of the polyhedrin promoter.

[0035] Another nuclear polyhedrosis virus-derived expression vector has been presented by Smith et al. (Gale E. Smith, Max D. Summers and M. J. Fraser, *Molecular and Cell Biology*, May 16, 1983, pp. 2156-2165). They have demonstrated the effectiveness of their vector through the expression of human  $\beta$ -interferon. The synthesized product was found to be glycosylated and secreted from insect cells, as would be expected. In Example 14, modifications to the plasmid containing the *Autographa californica* nuclear polyhedrosis virus (AcNPV) polyhedrin gene are described which allow the easy insertion of the EPO gene into the plasmid so that it may be under the transcriptional control of the polyhedrin promoter. The resulting DNA is co-transfected with intact chromosome DNA from wild type AcNPV into insect cells. A genetic recombination event results in the replacement of the AcNPV polyhedrin gene region with the DNA from the plasmid. The resulting recombinant virus can be identified amongst the viral progeny by its possession of the DNA sequences of the EPO gene. This recombinant virus, upon reinfection of insect cells is expected to produce EPO. [0036] Examples of EPO expression in CHO, C127 and 3T3, and insect cells are given in Examples 10 and 11 (CHO), 13 (C127 and 3T3) and 14 (insect cells).

[0037] Recombinant EPO produced in CHO cells as in Example 11 was purified by conventional column chromatographic methods. The relative amounts of sugars present in the glycoprotein were analyzed by two independent methods [(i) Reinhold, Methods in Enzymol. 50:244-249 (Methanolysis) and (ii) Takemoto, H. et al., Anal. Biochem. 145:245 (1985) (pyridyl) amination, together with independent sialic acid determination]. The results obtained by each of these methods were in excellent agreement. Several determinations were thus made, yielding the following average values wherein N-acetylglucosamine is, for comparative purposes, given a value of 1:

Sugar	Relative molar level
N-Acetylglucosamine	1
Hexoses:	1.4
Galactose	0.9

(continued)

Sugar	Relative molar level
Mannose	0.5
N-Acetylneuraminic acid	1
Fucose	0.2
N-Acetylglucosamine	0.1

[0038] It is noteworthy that significant levels of fucose and N-acetylglucosamine were reproducibly observed using both independent methods of sugar analysis. The presence of N-acetylglucosamine indicates the presence of O-linked glycosylation on the protein. The presence of O-linked glycosylation was further indicated by SDS-PAGE analysis of the glycoprotein following digestion of the glycoprotein with various combinations of glycosidic enzymes, in particular, following enzymatic removal of all N-linked carbohydrate on the glycoproteins using the enzyme peptide endo F N-glycosidase, the molecular weight of the protein was further reduced upon subsequent digestion with neuraminidase, as determined by SDS-PAGE analysis.

[0039] *In vitro* biological activity of the purified recombinant EPO was assayed by the method of G. Krystal, Exp. Hematol. 11:649 (1983) (spleen cell proliferation bioassay) with protein determinations calculated based upon amino acid compositional data. Upon multiple determinations, the *in vitro* specific activity of the purified recombinant EPO was calculated to be greater than 200,000 units/mg protein. The average value was in the range of about 275,000 - 300,000 units/mg protein. Moreover, values higher than 300,000 have also been observed. The *in vitro* (polycythemic mouse assay, Kazal and Eisler, Am. Clinical Lab. Sci., Vol. B, p. 91 (1975)) *in vitro* activity ratios observed for the recombinant material was in the range of 0.7 - 1.3.

[0040] It is interesting to compare the glycoprotein characterization presented above with the characterization for a recombinant CHO-produced EPO material previously reported in International Patent Application Publication No. WO 85/02610 (published 20 June 1985). The corresponding comparative sugar analysis described on page 65 of that application reported a value of zero for fucose and for N-acetylglucosamine and a hexoses:N-acetylglucosamine ratio of 15.08:1. The absence of N-acetylglucosamine indicates the absence of O-linked glycosylation in the previously reported glycoprotein. In contrast to that material, the recombinant CHO-produced EPO of this invention which is characterized above contains significant and reproducibly observable amounts of both fucose and N-acetylglucosamine, contains less than one-tenth the relative amount of hexoses and is characterized by the presence of O-linked glycosylation. Furthermore, the high specific activity of the above-described CHO-derived recombinant EPO of this invention may be directly related to its characteristic glycosylation pattern.

[0041] The biologically active EPO produced by the eucaryotic expression of the cloned EPO-DNA of claim 1 of the present invention can be used for the *in vivo* treatment of mammalian species by physicians and/or veterinarians. The amount of active ingredient will, of course, depend upon the severity of the condition being treated, the route of administration chosen, and the specific activity of the active EPO, and ultimately will be decided by the attending physician or veterinarian. Such amount of active EPO was determined by the attending physician is also referred to herein as an "EPO treatment effective" amount. For example, in the treatment of induced hypoproliferative anemia associated with chronic renal failure in sheep, an effective daily amount of EPO was found to be 10 units/kg for from 15 to 40 days. See Eschbach et al., J. Clin. Invest., 74:434 (1984).

[0042] The active EPO may be administered by any route appropriate to the condition being treated. Preferably, the EPO is injected into the bloodstream of the mammal being treated. It will be readily appreciated by those skilled in the art that the preferred route will vary with the condition being treated.

[0043] While it is possible for the active EPO to be administered as the pure or substantially pure compound, it is preferable to present it as a pharmaceutical formulation or preparation.

[0044] The formulations, both for veterinary and for human use, comprise an active EPO protein, as above described, together with one or more pharmaceutically acceptable carriers therefor and optionally other therapeutic ingredients. The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof. Desirably the formulation should not include oxidizing agents and other substances with which peptides are known to be incompatible. The formulations may conveniently be presented in unit dosage form and may be prepared by any of the methods well known in the art of pharmacy. All methods include the step of bringing into association the active ingredient with the carrier which constitutes one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association the active ingredient with liquid carriers or finely divided solid carriers or both, and then, if necessary, shaping the product into the desired formulation.

[0045] Formulations suitable for parenteral administration conveniently comprise sterile aqueous solutions of the

active ingredient with solutions which are preferably isotonic with the blood of the recipient. Such formulations may be conveniently prepared by dissolving solid active ingredient in water to produce an aqueous solution, and rendering said solution sterile may be presented in unit or multi-dose containers, for example sealed ampoules or vials.

[0046] EPO/cDNA as used herein includes the mature EPO/cDNA gene preceded by an ATG codon and of EPO protein (Met-EPO). The mature EPO protein is shown in Tables 2 and 3. The EPO protein includes the 1-methionine derivative Ala.Pro.Arg., the beginning of which is depicted by the number "1" in Table 2. The Met-EPO would begin with the sequence Met.Ala.Pro.Arg....

[0047] The following examples are provided to aid in the understanding of the present invention, the true scope of which is set forth in the appended claims. All temperatures are expressed in degrees Celsius and are uncorrected. The symbol for micron or micro, e. g., microliter, micromole, etc., is "μ", e.g., μl, μm, etc.

## EXAMPLES

### Example 1: Isolation of a Genomic Clone of EPO

[0048] EPO was purified from the urine of patients with aplastic anemia essentially as described previously (Miyake, et al., *J. Biol. Chem.*, 252:5558 (1977)) except that the phenol treatment was eliminated and replaced by heat treatment at 80 deg. for 5 min. to inactivate neuraminidase. The final step in the purification was fractionation on a C-4 Vydac HPLC column (The Separations Group) using 0 to 95% acetonitrile gradient with 0.1% trifluoroacetic acid (TFA) over 100 minutes. The position of EPO in the gradient was determined by gel electrophoresis and N-terminal sequence analysis (21, 26, 27) of the major peaks. The EPO was eluted at approximately 53% acetonitrile and represented approximately 40% of the protein subjected to reverse phase - HPLC. Fractions containing EPO were evaporated to 100 μl, adjusted to pH 7.0 with ammonium bicarbonate digested to completion with 2% TPCK-treated trypsin (Worthington) for 18 hrs. at 37 deg. The tryptic digestion was then subjected to reverse phase HPLC as described above. The optical density at both 280 and 214 nm was monitored. Well separated peaks were evaporated to near dryness, and subjected directly to N-terminal amino acid sequence analysis (59) using an Applied Biosystems Model 480A gas phase sequencer. The sequences obtained are underlined in Tables 2 and 3. As described herein SDS, two of these tryptic fragments were chosen for synthesis of oligonucleotide probes. From the sequence, Val-Asn-Phe-Tyr-Ala-Tyr-Lys (amino acids 46 through 52 in Tables 2 and 3), a 17mer of 32 fold degeneracy

TTCCANGCGTAGAAGTT

and an 18mer of 128 fold degeneracy

CCANGCGTAGAAGTTNAC

were prepared. From the sequence, Val-Tyr-Ser-Asn-Phe-Leu-Arg (amino acids 144 through 150 in Tables 2 and 3), two pools of 14mers,

each 32-fold degenerate

TACACCTAACITTCCT and TACACCTAAGTTCTT

which differ at the first position of the leucine codon were prepared. The oligonucleotides were labelled at the 5-prime end with <sup>32</sup>p using polynucleotide kinase (New England Biolabs) and gamma 32p-ATP (New England Nuclear). The specific activity of the oligonucleotides varied between 1000 and 3000 Ci/mole oligonucleotide. A human genomic DNA library in bacteriophage lambda (Lawn et al., 22) was screened using a modification of the *in situ* amplification procedure originally described by Woo et al., (47) (1978). Approximately 3.5 x 10<sup>6</sup> phages were plated at a density of 6000 phages per 150 mm petri dish (NZCYM media) and incubated at 37 deg. until the plaques were visible, but small (approximately 0.5 mm). After chilling at 4 deg. for 1 hr., duplicate replicas of the plaque patterns were transferred to nylon membranes (New England Nuclear) and incubated overnight at 37 deg. on fresh NZCYM plates. The filters were then denatured and neutralized by floating for 10 min. each on a thin film of 0.5N NaOH - 1M NaCl and 0.5M Tris (pH 8) - 1M NaCl respectively. Following vacuum baking at 80 deg. for 2 hrs., the filters were washed in 5 x SSC, 0.5% SDS for 1 hr. and the cellular debris on the filter surface was removed by gentle scrapping with a wet tissue. This scrapping reduced the background binding of the probe to the filters. The filters were then rinsed with H<sub>2</sub>O and prehybridized for from 4 to 8 hrs. at 48 deg. in 3M tetramethylammonium chloride, 10 mM NaPO<sub>4</sub> (pH 6.8), 5 x Denhardt's, 0.5% SDS and 10mM EDTA. The <sup>32</sup>p-labelled 17mer was then added at a concentration of 0.1 pmol/ml and hybridization was carried out at 48 deg. for 72 hrs. Following hybridization the filters were washed extensively in 2 x SSC (0.3M NaCl - 0.03M

Na citrate, pH 7) at room temperature and then for 1 hr. in 3M TMACl - 10mM NaPO<sub>4</sub> (pH 6.8) at room temperature and from 5 to 15 min. at the hybridization temperature. Approximately 120 strong duplicate signals were detected following 2 day autoradiography with an intensifying screen. The positives were picked, grouped in pools of 8, replated and rescreened in triplicate using one-half of the 14mer pool on each of two filters and the 127mer on the third filter. The conditions and the 17mer for plating and hybridization were as described supra except that hybridization for the 14mer was at 37 deg. Following autoradiography, the probe was removed from the 17mer filter in 50% formamide for 20 min. at room temperature and the filter was rehybridized at 52 deg. with the 18mer probe. Two independent phage hybridized to all three probes. DNA from one of these phage (designated herein, lambda HEPO1) was digested to completion with Sau3A and subcloned into M13 for DNA sequence analysis using the dideoxy chain termination method of Sanger and Coulson, (23) (1977). The nucleotide sequence and deduced amino acid sequence of the open reading frame coding for the EPO tryptic fragment (underlined region) are described herein. Intron sequences are given in lower case letters; exon sequences (87 nt) are given in upper case. Sequences which agree with consensus splice acceptor (a) and donor (d) sites are underlined. (See Table 4.)

### Example 2: Northern Analysis of Human Fetal Liver mRNA

[0049] 5 μg of human fetal liver mRNA (prepared from a 20 weeks old fetal liver) and adult liver mRNA were electro

TABLE 4 (CONT.)

2250	<p>           2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2815 2816 2817 2818 2819 2820 2821 2822 2823 2824 2825 2826 2827 2828 2829 2830 2831 2832 2833 2834 2835 2836 2837 2838 2839 2840 2841 2842 2843 2844 2845 2846 2847 2848 2849 2850 2851 2852 2853 2854 2855 2856 2857 2858 2859 2860 2861 2862 2863 2864 2865 2866 2867 2868 2869 2870 2871 2872 2873 2874 2875 2876 2877 2878 2879 2880 2881 2882 2883 2884 2885 2886 2887 2888 2889 2890 2891 2892 2893 2894 2895 2896 2897 2898 2899 2900 2901 2902 2903 2904 2905 2906 2907 2908 2909 2910 2911 2912 2913 2914 2915 2916 2917 2918 2919 2920 2921 2922 2923 2924 2925 2926 2927 2928 2929 2930 2931 2932 2933 2934 2935 2936 2937 2938 2939 2940 2941 2942 2943 2944 2945 2946 2947 2948 2949 2950 2951 2952 2953 2954 2955 2956 2957 2958 2959 2960 2961 2962 2963 2964 2965 2966 2967 2968 2969 2970 2971 2972 2973 2974 2975 2976 2977 2978 2979 2980 2981 2982 2983 2984 2985 2986 2987 2988 2989 2990 2991 2992 2993 2994 2995 2996 2997 2998 2999 3000         </p>
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55	50	45	40	35	30	25	20	15	10	5	
TABLE 5											
											gacagggaag gacgagctgg gacagagacg tggggatgaa
											LU CYS PRO TGT CCT
											ggaagctgtc ctccacagc cacccttctc cctccccgcc tgactctcag cctggctatc tgttctagAA
											ALA TRP LEU TRP LEU LEU LEU SER LEU LEU SER LEU PRO LEU GLY LEU PRO VAL LEU CYS GCC TCG CTG TCG CTT CTC CTC CTC TCC CTC CTC TCG CTC CTT CTG CCG CTC CCA CTC CTC TGT CCT
											1 Ala Pro Pro Arg Leu Ile SH GCC CCA CCA CCG CTC ATC TGT TCT Cys Asp Ser 10 CGA CCA CCA CCG CTC ATC TGT TCT CCA CCA CCA CCG CTC ATC TGT TCT CCA CCA CCA CCG CTC ATC TGT TCT
											20 Lys AAG
											30 Ala GCT
											40 Thr ACT
											50 Ala GCC
											60 Ala GCC
											70 Leu CTG
											80 Leu CTG
											90 Pro CCC
											100 Ser ACT
											110 Arg CGC
											120 Ser TCC
											130 Leu CTC
											140 Lys AAA

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TABLE 5 (CONT.)											
											150
											160
											Ala GCC
											Leu Phe Arg Val Tyr Ser Asn Phe Leu Arg Gly Lys Leu Lys Leu Tyr Thr Gly Glu CTC TTC CCA CTC TAC TCC AAT TTC CTC CCG GCA AAG CTG AAG CTC TAC ACA CCG GAG
											SH Cys Arg Thr Gly Asp Arg TCC ACC ACA CCG AAC ACA TCA ccaggtg
											tgccacctg
											ggcatatcca
											ccacctccct
											caccacatt
											gcttgtgcca
											cagctcagcg
											ccagctgtc
											ccatggacac
											agagggaactg
											aactctgaga
											tctaaggatg
											gagagcagct
											ttaactcag
											ggacagagcc
											acctgcaaa
											atttgatgcc
											aggacacgct
											ttggagggcga
											tgaggaactt
											aggtggcgaag
											ctgtgacttc
											ggaggcaaga
											gcccccttga
											caccggggtg
											gtgggaacca
											ctcatggggt
											ccaagttttg
											tgtattcttc
											aactctattg
											ncaugnaactg
											aaaccaccaa
											aaaaaaaaaaaa

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TABLE 6

cccggccg

ctcgcgtgcgc	tgccgcgcac	cgcgctgtcc	tcccggagcc	ggaccggggc	caccgcgccc	gctctgctccg	acaccgcgcc												
ccctggacag	ccgccctctc	ct-caggccc	gtggggctgg	ccctgcaccg	ccgagcttcc	cgggatgagg	ccccgggtgt												
ggtcacccgg	cgcgccccag	gtcgctgagg	gaccccgggc	aggcgcgagg	-17 MET	GLY	VAL	HIS	GLU	CYS	PRO								
ALA	TRP	LEU	TRP	LEU	LEU	LEU	SER	LEU	LEU	SER	LEU	PRO	LEU	GLY	LEU	PRO	VAL	LEU	GLY
GCC	TGG	CTG	TGG	CTT	CTC	CTC	TCC	CTG	CTC	TGG	CTC	CCT	CTC	GCG	CTC	CCA	GTC	CTG	GCC
1						SH				10									20
Ala	Pro	Pro	Arg	Leu	Ile	Cys	Asp	Ser	Arg	Arg	Val	Leu	Glu	Arg	Tyr	Leu	Leu	Glu	Ala
GCC	CCA	CCA	CGC	CTC	ATC	TCT	GAC	AGC	CGA	CGA	GTC	CTG	GAG	AGC	TAC	CTC	TTC	GAG	GCC
			*					SH		30			SH				*		40
Glu	Ala	Glu	Asn	Ile	Thr	Thr	Gly	Cys	Ala	Glu	His	Cys	Ser	Leu	Asn	Glu	Asn	Ile	Thr
GAC	GCC	GAC	AAT	ATC	ACG	ACC	GCC	TCT	GCT	GAA	CAC	TGC	AGC	TTC	AAT	GAC	AAT	ATC	ACT
									50										60
Val	Pro	Asp	Thr	Lys	Val	Asn	Phe	Tyr	Ala	Trp	Lys	Arg	Met	Glu	Val	Gly	Gln	Gln	Ala
CTC	CCA	CAC	ACC	AAA	CTT	AAT	TTC	TAT	GCC	TGG	AAG	ACG	ATG	CAC	CTC	GGG	CAC	CAG	GCC
									70										80
Val	Glu	Val	Trp	Gln	Gly	Leu	Ala	Leu	Leu	Ser	Glu	Ala	Val	Leu	Arg	Gly	Gln	Ala	Leu
CTA	GAA	GTC	TGG	CAG	GCC	CTG	GCC	CTG	CTC	TGG	GAA	GCT	GTC	CTG	CGG	GCC	CAG	GCC	CTG

TABLE 6 (CONT.)

Leu	Val	Asn	Ser	Ser	Gln	Pro	Trp	Glu	Pro	Leu	Gln	Leu	His	Val	Asp	Lys	Ala	Val	100
TTC	CTC	AAC	TCT	TCC	CAG	CCG	TGG	GAC	CCC	CTG	CAG	CTG	CAT	GTC	GAT	AAA	GCC	GTC	Ser
		*							90										100
Gly	Leu	Arg	Ser	Leu	Thr	Thr	Leu	Leu	Arg	Ala	Leu	Gly	Ala	Gln	Lys	Glu	Ala	Ile	120
GCC	CTT	CGC	ACC	CTC	ACC	ACT	CTG	CTT	CGG	GCT	CTG	GGA	GCC	CAC	AAG	GAA	CCC	ATC	Ser
									110										120
Pro	Pro	Asp	Ala	Ala	Ser	Ala	Ala	Pro	Leu	Arg	Thr	Ile	Thr	Ala	Asp	Thr	Phe	Arg	140
CCT	CCA	CAT	CGC	CCC	TCA	GCT	GCT	CCA	CTC	CCA	ACA	ATC	ACT	GCT	GAC	ACT	TTC	CGC	Lys
									130										140
Leu	Phe	Arg	Val	Tyr	Ser	Asn	Phe	Leu	Arg	Gly	Lys	Leu	Lys	Leu	Tyr	Thr	Gly	Glu	150
CTC	TTC	CCA	GTC	TAC	TCC	AAT	TTC	CTC	CGG	GCA	AAG	CTG	AAC	CTG	TAC	ACA	GCG	CAG	CTG

TABLE 7

TABLE 7										cccggagccc		ggaccggggc		caccgcgcgc		gtctgtctccg		acaccggccc	
ccctggacag		cgcgccctctc		ctccaggccc		gtggggctgg		ccctgcaccc		ccgagcttcc		cgggatggggg		ccccgggtgt					
ggtcaccggb		cgcgccccag		gtcgtctagg		gaccccgggc		agtcgctggag		-27 MET ATC		GLY CGC	VAL GTC	HIS CAC	GLU GAA ▲	CYS TGT	PRO CCT		
ALA GCC	TRP TGG	LEU CTG	TRP TGG	LEU CTT	LEU CTC	LEU CTG	SER TCC	LEU CTG	LEU CTG	SER TCC	LEU CTC	PRO CCT	LEU CTG	GLY GCC	LEU CTC	PRO CCA	VAL GTC	LEU CTG	GLY GGC
1																			
Ala	Pro	Pro	Arg	Leu	Ile	SH Cys	Asp	Ser	10 Arg	Val	Leu	Glu	Arg	Tyr	Leu	Leu	Glu	Ala	20 Lys
GCC	CCA	CCA	CGC	CTC	ATC	TCT	CAC	AGC	CGA	GTC	CTG	GAG	AGC	TAC	CTC	TTC	CAG	GCC	AAC
SH																			
Glu	Ala	Glu	* Asn	Ile	Thr	Thr	Gly	Cys	30 Ala	Glu	His	Cys	Ser	Leu	Asn	Glu	Asn	Ile	40 Thr
CAG	CCC	CAG	AAT	ATC	ACC	ACC	CCC	TGT	GCT	GAA	CAC	TCC	AGC	TTC	AAT	CAG	AAT	ATC	ACT
SH																			
Val	Pro	Asp	Thr	Lys	Val	Asn	Phe	Tyr	50 Ala	Trp	Lys	Arg	Met	Glu	Val	Gly	Gln	Gln	60 Ala
CTC	CCA	GAC	ACC	AAA	CTT	AAT	TTC	TAT	GCC	TGG	AAC	AGG	ATG	GAG	GTC	GCG	CAG	CAG	GCC
70																			
Val	Glu	Val	Trp	Gln	Gly	Leu	Ala	Leu	Leu	Ser	Glu	Ala	Val	Leu	Arg	Gly	Gln	Ala	80 Leu
CTA	GAA	CTC	TCC	CAG	GCC	CTG	GCC	CTG	CTC	TCC	GAA	GCT	GTC	CTC	CGG	GCC	CAG	GCC	CTG
90																			
Leu	Val	Asn	Ser	Ser	Gln	Pro	Trp	Glu	Pro	Leu	Gln	Leu	His	Val	Asp	Lys	Ala	Val	100 Ser
TTC	GTC	AAC	TCT	TCC	CAG	CCG	TGG	GAG	CCC	CTG	CAG	CTG	CAT	GTC	GAT	AAA	GCC	GTC	ACT
110																			
Gly	Leu	Arg	Ser	Leu	Thr	Thr	Leu	Leu	Arg	Ala	Leu	Gly	Ala	Gln	Lys	Glu	Ala	Ile	120 Ser
GGC	CTT	CCG	AGC	CTC	ACC	ACT	CTG	CTT	CGC	GCT	CTG	GGA	CCC	CAG	AAG	GAA	GCC	ATC	TCC

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TABLE 7 (CONT.)

																			130																				140
Pro	Pro	Asp	Ala	Ala	Ser	Ala	Ala	Pro	Leu	Arg	Thr	Ile	Thr	Ala	Asp	Thr	Phe	Arg	Lys																				
CCT	CCA	CAT	CCG	CCC	TCA	GCT	GCT	CCA	CTC	CGA	ACA	ATC	ACT	GCT	GAC	ACT	TTC	CGC	AAA																				
																			150																				160
Leu	Phe	Arg	Val	Tyr	Ser	Asn	Phe	Leu	Arg	Gly	Lys	Leu	Lys	Leu	Tyr	Thr	Gly	Glu	Ala																				
CTC	TTC	CGA	GTC	TAC	TCC	AAT	TTC	CTC	CGG	GGA	AAG	CTG	AAG	CTC	TAC	ACA	GGG	GAG	GCC																				
SH					166																																		
Cys	Arg	Thr	Gly	Asp	Arg	.																																	
TCC	ACG	ACA	GCC	GAC	AGA	TGA	ccaggtg	tgctccacctg	ggcatatcca	ccacctccct	cuccnacatt																												
gcttgtgcca			caccctcccc			cgccactccct			gaaccccgctc			gaggggctct			cagctcagcg			ccagcctgtc																					
ccatggacac			tcacgtgcca			gcantgncat			ctcaggggccc			agagggaactg			tcacagagagc			aactctgaga																					
ctcagggtg			tcacaggggcc			aacttgaggg			cccagagcag			gaagcattca			gagagcngct			ttaaactcag																					
ggacagagcc			atgctgggaa			gacgcctgag			ctcactcggc			accctgcana			atttgatgcc			aggacacgct																					
ctggaggcga			tttacctgtt			ttcgacccta			ccatcaggga			caggatgacc			tggagaactt			aggtggcaag																					
ctgtgacttc			tcacaggctc			acgggcatgg			gcactccctt			ggtggcaga			gtccccctga			caccgggggtg																					
gtgggaacca			tgagagcagg			atggggctctg			gcctctggct			ctcatgggg			ccaagttttg			tgtattcttc																					
aacctcattg			acaagaactg			aaccaacca			aaaaaaaaaaaa																														

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[0051] With reference to Tables 2 and 3, the deduced amino acid sequence shown below the nucleotide sequence is numbered beginning with 1 for the first amino acid of the mature protein. The putative leader peptide is indicated by

all caps for the amino acid designations. Cysteine residues in the mature protein are additionally indicated by SH and potential N-linked glycosylation sites by an asterisk. The amino acids which are underlined indicate those residues identified by N-terminal protein sequencing or by sequencing tryptic fragments of EPO as described in Example 1. Partial underlining indicates residues in the amino acid sequence of certain tryptic fragments which could not be determined unambiguously. The cDNA clones lambdaHEPOFL6, lambdaHEPOFL8 and lambdaHEPOFL13 have been deposited and are available from the American Type Culture Collection, Rockville, Maryland as Accession Numbers ATCC 40156, ATCC 40152 and ATCC 40153, respectively.

#### Example 4: Genomic Structure of the EPO Gene

[0052] The relative sizes and positions of four independent genomic clones (lambda-HEPO1, 2, 3, and 6) from the Haell/AluI library are illustrated by the overlapping lines in Figure 3. The thickened line indicates the position of the EPO gene. A scale (in kb) and the positions of known restriction endonuclease cleavage sites are shown. The region containing the EPO gene was completely sequenced from both strands using directed exonuclease III generated series of deletions through this region. A schematic representation of five exons coding for EPO mRNAs is shown in Figure 4. The precise 5-prime boundary of exon 1 is presently unknown. The protein coding portion of the exons are darkened. The complete nucleotide sequence of the region is shown in Table 4. The known limits of each exon are delineated by the solid vertical bars. Genomic clones lambda-HEPO1, lambda-HEPO2, lambda-HEPO3 and lambda HEPO6 have been deposited and are available from the American Type Culture Collection, Rockville, Maryland as Accession Numbers ATCC 40154, ATCC 40155, ATCC 40150, and ATCC 40151, respectively.

#### Example 5: Construction of Vector p91023(b)

[0053] The transformation vector was pAdD26SVpA(3) described by Kaufman et al., *Mol. Cell Biol.*, 2:1304 (1982). The structure of this vector is shown in Fig. 5A. Briefly, this plasmid contains a mouse dihydrofolate reductase (DHFR) cDNA gene that is under transcriptional control of the adenovirus 2 (Ad2) major late promoter. A 5-prime splice site is indicated in the adenovirus DNA and a 3-prime splice site, derived from an immunoglobulin gene, is present between the Ad2 major late promoter and the DHFR coding sequence. The SV40 early polyadenylation site is present downstream from the DHFR coding sequence. The procaryotic-derived section of pAdD26SVpA(3) is from pSV0d (Mellon et al., *Cell*, 27: 279 (1981)) and does not contain the pBR322 sequences known to inhibit replication in mammalian cells (Lusky et al., *Nature*, 263: 79 (1981)).

[0054] pAdD26SVpA(3) was converted to plasmid pCVSVL2 as illustrated in Fig. 5A. pAdD26SVpA(3) was converted to plasmid pAdD26SVpA(3)(d) by the deletion of one of the two PstI sites in pAdD26SVpA(3). This was accomplished by a partial digestion with PstI using a 0.5 unit of enzyme such that a subpopulation of linearized plasmids are obtained in which only one PstI site was cleaved, followed by treatment with Klenow, ligation to recircularize, and screening for deletion of the PstI site located 3-prime to the SV40 polyadenylation sequence.

[0055] The adenovirus tripartite leader and virus associated genes (VA genes) were inserted into pAdD26SVpA(3)(d) as illustrated in Fig. 5A. First, pAdD26SVpA(3)(d) was cleaved with PvuII to make a linear molecule opened within the 3-prime portion of the three elements comprising the tripartite leader. Then, pJAW 43 (Zain et al., *Cell*, 16: 851 (1979)) was digested with Xho 1, treated with Klenow, digested with PvuII, and the 140bp fragment containing the second part of the third leader was isolated by electrophoresis on an acrylamide gel (6% in the borate buffer; Maniatis et al., *EMBO*). The 140bp fragment was then ligated to the PvuII digested pAdD26SVpA(3)(d). The ligation product was used to transform *E. coli* to tetracycline resistance and colonies were screened using the Grunstein-Hogness procedure employing a <sup>32</sup>P labelled probe hybridizing to the 140bp fragment. DNA was prepared from positively hybridizing colonies to test whether the PvuII site reconstructed was 5-prime or 3-prime of the inserted 140bp DNA specific to the second and third adenovirus late leaders. The correct orientation of the PvuII site is on the 5-prime side of the 140bp insert. This plasmid is designated ITPL in Fig. 5A.

[0056] The Ava II D fragment of SV40 containing the SV40 enhancer sequence was obtained by digesting SV40 DNA with Ava II, bluntending the ends with the Klenow fragment of Pst I, ligating Xho 1 linkers to the fragments, digesting with Xho 1 to open the Xho 1 site, and isolating the fourth largest (D) fragment by gel electrophoresis. This fragment was then ligated to Xho 1 cut pTFL, yielding the plasmid pCVSVL2-TPL. The orientation of the SV40 D fragment in pCVSVL2-TPL was such that the SV40 late promoter was in the same orientation as the adenovirus major late promoter.

[0057] To introduce the adenovirus associated (VA) genes into the pCVSVL2-TPL, first a plasmid pBR322 was constructed that contained the adenovirus type 2 Hind III B fragment. Adenovirus type 2 DNA was digested with Hind III and the B fragment was isolated by gel electrophoresis. This fragment was inserted into pBR322 which had previously been digested with Hind III. After transformation of *E. coli* to ampicillin resistance, recombinants were screened for insertion of the Hind III B fragment and the inserted orientation was determined by restriction enzyme digestion.

pBR322 - Ad Hind III B contains the adenovirus type 2 Hind III B fragment in the orientation depicted in Fig. 5B.

[0058] As illustrated in Fig. 5B, the VA genes are conveniently obtained from plasmid pBR322 - Ad Hind III B by digestion with Hpa I, adding EcoRI linkers and digestion with EcoRI, followed by recovery of the 1.4kb fragment. The fragment having EcoRI sticky ends is then ligated into the EcoRI site of PTL, previously digested with EcoRI. After transforming *E. coli* HB101 and selecting for tetracycline resistance, colonies were screened by filter hybridization to DNA specific for the VA genes. DNA was prepared from positively hybridizing clones and characterized by restriction endonuclease digestion. The resulting plasmid is designated p91023.

[0059] As illustrated in Fig. 5C, the two EcoRI sites in p91023 were removed by cutting p91023 to completion with EcoRI, generating two DNA fragments, one about 7kb and the other about 1.3kb. The latter fragment contained the VA genes. The ends of both fragments were filled in using the Klenow fragment of Pst I and the two fragments were then ligated together. A plasmid p91023(A), containing the VA genes and similar to p91023, but deleted for the two EcoRI sites, were identified by Grunstein-Hogness screening with the VA gene fragment, and by conventional restriction site analysis.

[0060] The single PstI site in p91023(A) was removed and replaced with an EcoRI site. p91023(a) was cut to completion with PstI and treated with the Klenow fragment of Pst I to generate flush ends. EcoRI linkers were ligated to the bluntended PstI site of p91023(A). The linear p91023(A), with EcoRI linkers attached at the bluntended PstI site was separated from unligated linkers and digested to completion with EcoRI, and religated. A plasmid, p91023(B) as depicted in Figure 5C was recovered, and identified as having a structure similar to p91023(A), but with an EcoRI site in place of the former PstI site. Plasmid p91023(B) has been deposited and is available from the American Type Culture Collection, Rockville, Maryland as Accession Number ATCC 39754.

#### Example 6:

[0061] The cDNA clones (lambda-EPOFL6 and lambda-EPOFL13; Example 3) were inserted into the plasmid p91023(B) forming pPTFL6 and pPTFL13, respectively. 8 µg of each of the purified DNA's was then used to transfect 5 x 10<sup>6</sup> COS cells using the DEAE-dextran method (Iltis). After 12 hrs., the cells were washed and treated with Chloroquin (0.1mM) for 2 hrs., washed again, and exposed to 10 ml media containing 10% fetal calf serum for 24 hrs. The media was changed to 4 ml serum free media and harvested 48 hrs. later.

[0062] Production of immunologically active EPO was quantified by a radioimmunoassay as described by Sherwood and Goldwasser (55). The antibody was provided by Dr. Judith Sherwood. The iodinated tracer was prepared from the homogeneous EPO described in Example 1. The sensitivity of the assay is approximately 1ng/ml. The results are shown below in Table 8.

TABLE 8

VECTOR	LEVEL OF EPO RELEASED INTO THE MEDIA (ng/ml)
pPTFL13	330
pPTFL6	31

[0063] PTFL13 has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39990.

#### Example 7

[0064] EPO cDNA (lambda-HEPOFL13) was inserted into the p91023(B) vector and was transfected into COS-1 cells and harvested as described above (Example 6) except that the chloroquin treatment was omitted.

[0065] *In vitro* biologically active EPO was measured using either a colony forming assay with mouse fetal liver cells as a source of CFU-E or a <sup>3</sup>H-thymidine uptake assay using spleen cells from phenylhydrazine injected mice. The sensitivities of these assays are approximately 25 mUnits/ml. *In vivo* biologically active EPO was measured using either the hypoxic mouse or starved rat method. The sensitivity of these assays is approximately 100 mU/ml. No activity was detected in either assay from mock condition media. The results of EPO expressed by clone EPOFL13 are shown below in Table 9 wherein the activities reported are expressed in units/ml, using a commercial, quantified EPO (Toyobo, Inc.) as a standard.

TABLE 9

EPO Excreted from COS Cells Transfected with Type I EPO cDNA		
Assay	Activity	
RIA	100	ng/ml
CFU-E	2	0.5 U/ml
<sup>3</sup> H-Thy	3.1	1.8 U/ml
hypoxic mouse	1	U/ml
starved rat	2	U/ml

#### Example 8: SDS Polyacrylamide Gel Analysis of EPO from COS Cells

[0066] 180 ng of EPO released into the media of COS cells transfected with EPO (lambda-HEPFL13) cDNA in the vector p91023(B) (su2a) was electrophoresed on a 10% SDS Laemmli polyacrylamide gel and electrotransferred to nitrocellulose paper (Towbin et al., *Proc. Natl. Acad. Sci. USA* 76:4350 (1979)). The filter was probed with anti-EPO antibody as described in Table 8, washed, and re-probed with <sup>125</sup>I-staph A protein. The filter was autoradiographed for two days. Native homogeneous EPO was described in Example 1, either before (lane B) or after iodination (lane C) were electrophoresed (see Figure 6). Markers used included <sup>35</sup>S methionine labelled, serum albumin (68,000 d) and ovalbumin (45,000 d).

#### Example 9: Construction of RK1-4

[0067] The Bam HI-PvuII fragment from the plasmid pSV2DHFR (Subramani et al., *Mol. Cell. Biol.* 1:854-864 (1981)) containing the SV40 early region promoter adjacent to the mouse dihydrofolate reductase (DHFR) gene, an SV40 enhancer, the small t antigen intron, and the SV40 polyadenylation sequence was isolated (fragment A). The remaining fragments were obtained from the vector p91023(A) (su2a) as follows: p91023(A) was digested with Pst I at the single Pst I site near to the adenovirus promoter to linearize the plasmid and either ligated to synthetic Pst I to EcoRI converters and recircularized (creating the sites Pst I - EcoRI - Pst I at the original Pst I site; 91023(B)) or treated with the large fragment of DNA polymerase I to destroy the Pst I sites and ligated to a synthetic EcoRI linker and recircularized (creating an EcoRI site at the original Pst I site; 91023(B)). Each of the two resulting plasmids 91023(B) and 91023(B') were digested with Xba and EcoRI to produce two fragments (F and G). By joining fragment F from p91023(B) and fragment G from p91023(B') and fragment G from p91023(B) and fragment F from p91023(B') two new plasmids were created which contained either an EcoRI - Pst I site or a Pst I - EcoRI site at the original Pst I site. The plasmid containing the Pst I - EcoRI site where the Pst I site is closest to the adenovirus major late promoter was termed p91023(C).

[0068] The vector p91023(C) was digested with XhoI to completion and the resulting linearized DNA with sticky ends was bluntly by an end filling reaction with the large fragment of *E. coli* of DNA polymerase I. To this DNA was ligated a 340 bp Hind III - EcoRI fragment containing the SV40 enhancer prepared as follows:

[0069] The Hind III - Pvu II fragment from SV40 which contains the SV40 origin or replication and the enhancer was inserted into the plasmid c lac (Little et al., *Mol. Biol. Med.* 1:473-488 (1983)). The c lac vector was prepared by digesting c lac DNA with BamHI, filling in the sticky ends with the large fragment of DNA polymerase I and digesting the DNA with Hind III. The resulting plasmid (c SVHP/c) regenerated the BamHI site by ligation to the Pvu II blunt end. The EcoRI - Hind III fragment was prepared from c SVHP/c and ligated to the EcoRI - Hind III fragment of pSV2D (Mellon et al., *su2a*) which contained the plasmid origin of replication and the resulting plasmid pSVHP/c was selected. The 340 bp EcoRI - Hind III fragment of pSVHP/c containing the SV40 origin/enhancer was then prepared, bluntly at both ends with the large fragment of DNA polymerase I, and ligated to the XhoI digested, bluntly p91023(C) vector described above. The resulting plasmid p91023 (C)/XhoI/bunt plus EcoRI/Hind III/bunt SV40 origin plus enhancer) in which the orientation of the Hind III - EcoRI fragment was such that the BamHI site within that fragment was nearest to the VA gene was termed pES105. The plasmid pES105 was digested with Bam HI and PvuII and also with PvuII alone and the BamHI - PvuII fragment containing the adenovirus major late promoter (fragment B) and the PvuII fragment containing the plasmid during resistance gene (tetracycline resistance) and other sequences (fragment C) were isolated. Fragments A, B and C were ligated and the resulting plasmid shown in Figure 7 was isolated and termed RK1-4. Plas-

mid RK1-4 has been deposited with the American Type Culture Collection, Rockville, Maryland, where it is available under Accession Number ATCC 39940.

#### Example 10: Expression of EPO in CHO cells-Method I

[0070] DNA (20 ug) from the plasmid pPTFL13 described above (Example 6) was digested with the restriction endonuclease Cla I to linearize the plasmid and was ligated to Cla I-digested DNA from the plasmid pAd2SVn(A) 1 (2 ug) which contains an intact dihydrofolate reductase (DHFR) gene driven by an adenovirus major late promoter (Kaufman and Sharp, *Mol. and Cell Biol.* 2:1304-1318 (1982)). This ligated DNA was used to transfect DHFR-negative CHO cells (DUKX-BII, Chasin L.A. and Uriaub G. (1980) *PNAS* 77 4216-4220) and following growth for two days, cells which incorporated at least one DHFR gene were selected in alpha media lacking nucleotides and supplemented with 10% dialyzed fetal bovine serum. Following growth for two weeks in selective media, colonies were removed from the original plates, pooled into groups of 10-100 colonies per pool, replated and grown to confluence in alpha media lacking nucleotides. The supernatant media from the pools grown prior to methotrexate selection were assayed for EPO by RIA. Pools which showed positive EPO production were grown in the presence of methotrexate (0.02 uM) and then sub-cloned and reassayed. EPO Cla 4.02-7, a single subcloned from the EPO Cla 4.02 pool, releases 460 ng/ml EPO into media containing 0.02 uM MTX (Table 10). EPO Cla 4.02-7 is the cell line of choice for EPO production and has been deposited with the American Type Culture Collection as Accession Number ATCC CRL8695. Currently, this clone is being subjected to stepwise selection in increasing concentrations of MTX, and will presumably yield cells which produce even higher levels of EPO. For pools which were negative by RIA, methotrexate resistant colonies obtained from the counterpart cultures which were grown in the presence of methotrexate (0.02 uM) were again reassayed in pools for EPO by RIA. Those cultures which were not positive were subcloned and subjected to growth in further increasing concentrations of methotrexate.

[0071] Stepwise methotrexate (MTX) selection was achieved by repeated cycles of culturing the cells in the presence of increasing concentrations of methotrexate and selecting for survivors. At each round, EPO was measured in the culture supernatant by RIA and by in vitro biological activity. The levels of methotrexate used in each stepwise amplification were 0.02 uM, 0.1 uM, and .5 uM. As shown in Table 10 after 1 round of selection in .02 uM MTX significant levels of EPO were being released into the culture media.

TABLE 10

Sample	Level of EPO Released into the Media		
	Assay	Alpha medium harvest	0.02 uM methotrexate in alpha medium harvest
4 4	Pool	RIA	17 ng/ml
4 4	Single Colony	RIA	50 ng/ml
	Clone (.02-7)	RIA	460 ng/ml

#### Example 11: Expression of EPO in CHO cells - Method II

[0072] DNA from the clone lambda HEPFL13 was digested with EcoRI and the small RI fragment containing the EPO gene was subcloned into the EcoRI site of the plasmid RK1-4 (See Example 10). This DNA (RKFL13) was then used to transfect the DHFR-negative CHO cells directly (without digestion) and the selection and amplification was carried out as described in Example 10 above.

[0073] The RKFL13 DNA was also inserted into CHO cells by protoplast fusion and microinjection. Plasmid RKFL13 has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39989.

TABLE 11

Sample	Level of EPO Released into the Media		
	Assay	alpha medium harvest	0, 02uM methotrexate in alpha medium harvest
Colony Pool A	RIA	3 ng/ml	42 ng/ml (pool)
Single Colony clone(02C-Z)	<sup>3</sup> H-Thy	-	150 ng/ml (clone)
	RIA	-	1.5 U/ml
Microinjected pool (DEPO-I)	<sup>3</sup> H-Thy	-	90 ng/ml
	RIA	60 ng/ml	5.9 U/ml
	<sup>3</sup> H-Thy	1.8 U/ml	180 ng/ml
			-

[0074] The preferred single colony clone has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession Number ATCC CRL8695.

#### Example 12: Expression of EPO Genomic Clones in COS-1 Cells

[0075] The vector used for expression of the EPO genomic clone is pSVOD (Mellon et al., supra). DNA from pSVOD was digested to completion with Hind III and bunted with the large fragment of DNA polymerase I. The EPO genomic clone lambda-HEPO3 was digested to completion with EcoRI and Hind III and the 4.0 kb fragment containing the EPO gene was isolated and bunted as above. The nucleotide sequence of this fragment from the Hind III site to a region just beyond the polyadenylation signal is shown in Figure 4 and Table 4. The EPO gene fragment was inserted into the pSVOD plasmid fragment and correctly constructed recombinants in both orientations were isolated and verified. The plasmid C22-1 has the EPO gene in orientation "a" (i.e. with the 5' end of EPO nearest to the SV40 origin) and the plasmid C21-3 is in the opposite orientation (orientation "b").

[0076] The plasmids C21-3 and C22-1 were transfected into COS-1 cells as described in Example 7 and media was harvested and assayed for immunologically reactive EPO. Approximately 31 ng/ml of EPO was detected in the culture supernatant from C22-1 and 16-31 ng/ml from C21-3.

[0077] Genomic clones HEPO1, HEPO2, and HEPO6 can be inserted into COS cells for expression in a similar manner.

#### Example 13: Expression in C127 and in 3T3 Cells Construction of pBPV-EPO

[0078] A plasmid containing the EPO cDNA sequence under the transcriptional control of a mouse metallothionein promoter and linked to the complete bovine papilloma virus DNA was prepared as follows:

##### pEPO15a

[0079] The plasmid SP6/5 was purchased from Promega Biotec. This plasmid was digested to completion with EcoRI and the 1340 bp EcoRI fragment from lambda-HEPOFL13 was inserted by DNA ligase. A resulting plasmid in which the 5' end of the EPO gene was nearest to the SP6 promoter (as determined by BglII and Hind III digestion) was termed pEPO49F. In this orientation, the BamHI site in the PSP6/5 polylinker is directly adjacent to the 5' end of the EPO gene.

##### pMMTneo BPV

[0080] The plasmid pBPV-MMTneo (342-12) (Law et al., Mol. and Cell Biol. 3:2110-2115 (1983)), illustrated in Figure 8, was digested to completion with BamHI to produce two fragments - a large fragment -8kb in length containing the BPV genome and a smaller fragment, -6.5 kb in length, containing the pML2 origin of replication and ampicillin resistance gene, the metallothionein promoter, the neomycin resistance gene, and the SV40 polyadenylation signal. The digested DNA was recircularized by DNA ligase and plasmids which contained only the 6.8 kb fragment were identified by EcoRI and BamHI restriction endonuclease digestion. One such plasmid was termed pMMTneo BPV.

##### pEPO15a

[0081] pMMTneo BPV was digested to completion with BglII. pEPO49F was digested to completion with BamHI and BglII and the approximately 700 bp fragment containing the entire EPO coding region was prepared by gel isolation. The BglII digested pMMTneo BPV and the 700 bp BamHI/BglII EPO fragment were ligated and resulting plasmids containing the EPO cDNA were identified by colony hybridization with an oligonucleotide d(GGTCATCTGTCCTGTC) probe which is specific for the EPO gene. Of the plasmids which were positive by hybridization analysis, one (pEPO15a) which had the EPO cDNA in the orientation such that the 5' end of the EPO cDNA was nearest to the metallothionein promoter was identified by digestion with EcoRI and KpnI.

##### pBPV-EPO

[0082] The plasmid pEPO15a was digested to completion with BamHI to linearize the plasmid. The plasmid pBPV-MMTneo(342-12) was also digested to completion with BamHI to produce two fragments of 6.5 and 8kb. The 8kb fragment which contained the entire Bovine Papilloma Virus genome, was gel isolated. pEPO15a/BamHI and the 8kb BamHI fragment were ligated together and a plasmid (pBPV-EPO) which contained the BPV fragment was identified by colony hybridization using an oligonucleotide probe d(P-CCACACCGGTACACA-OH) which is specific for the BPV genome. Digestion of pBPV-EPO DNA with Hind III indicated that the direction of transcription of the BPV genome was the same as the direction of transcription from the metallothionein promoter (as in pBPV-MMTneo(342-12) see Figure 8). The plasmid pBPV-MMTneo(342-12) is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 37224.

##### Expression

[0083] The following methods were used to express EPO.

##### Method I:

[0084] DNA pBPV-EPO was prepared and approximately 25 ug was used to transfect  $\sim 1 \times 10^6$  C127 (Lowy et al., J. of Virol. 26:291-98 (1978)) CHO cells using standard calcium phosphate precipitation techniques (Graham et al., Virol. 52:456-67 (1973)). Five hrs. after transfection, the transfection media was removed, the cells were glycerol shocked, washed, and fresh  $\alpha$ -medium containing 10% fetal bovine serum was added. Forty-eight hrs. later, the cells were trypsinized and split at a ratio of 1:10 in DME medium containing 500 ug/ml G418 (Southern et al., Mol. Appl. Genet. 1:327-41 (1982)) and the cells were incubated for two-three weeks. G418 resistant colonies were then isolated individually into microtiter wells and grown until sub-confluent in the presence of G418. The cells were then washed, fresh media containing 10% fetal bovine serum was added and the media was harvested 24 hours later. The conditioned media was tested and shown to be positive for EPO by radioimmunoassay and by *in vitro* biological assay.

##### Method II

[0085] C127 or 3T3 cells were cotransfected with 25ug of pBPV-EPO and 2ug of pSV2neo (Southern et al., supra) as described in Method I. This is approximately at 10-fold molar excess of the pBPV-EPO. Following transfection, the procedure is the same as in Method I.

##### Method III

[0086] C127 cells were transfected with 30 ug of pBPV-EPO as described in Method I. Following transfection and splitting (1:10), fresh media was exchanged every three days. After approximately 2 weeks, foci of BPV transformed monolayer and assayed for EPO activity or antigenicity in the conditioned media.

#### Example 14: Expression in Insect cells Construction of pIVEP EPOEL13

[0087] The plasmid vector pIVEP has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39991. The vector was modified as follows:

pIVEVNI

[0098] pIVEV was digested with EcoRI to linearize the plasmid, blunted using the large fragment of DNA polymerase I and a single NotI linker

GGCGCGCGCC  
CCGCGCGCGG

was inserted by blunt end ligation. The resultant plasmid is termed pIVEVNI.

pIVEVSI

[0099] pIVEV was digested with SmaI to linearize the plasmid and a single SfiI linker

GGGCCCCAGGGGGCC  
CCGCGGGTCCCCGGG

was inserted by blunt end ligation. The resultant plasmid was termed pIVEVSI.

pIVEVSIgKp

[0099] The plasmid pIVEVSI was digested with KpnI to linearize the plasmid and approximately 0 to 100 bp were removed from each end by digestion with the double-stranded exonuclease Bal 31. Any resulting ends which were not perfectly blunt were blunted using the large fragment of DNA polymerase I and the polylinker

```

      Xho I   Xba I
      |       |
      Bgl II  Kpn I
      |       |
      AGATCTCGAATCTTACGATCGATGCTAC
      TCTAGACTCTTAAAGATCTAGTACCATGG
  
```

was inserted by blunt end ligation. The polylinker was inserted in both orientations. A plasmid in which the polylinker is oriented such that the BglII site within the polylinker is nearest to the polyhedron gene promoter is termed pIVEVSIgKp. A plasmid in which the KpnI site within the polylinker is nearest to the polyhedron gene promoter is termed pIVEVSIgKpBg. The number of base pairs which were deleted between the original KpnI site in pIVEVSI and the polyhedron promoter was not determined. The pIVEVSIgKp has been deposited with and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39988.

pIVEVSIgKpNI

[0091] pIVEVNI was digested to completion with KpnI and PstI to produce two fragments. The larger fragment, which contained the plasmid origin of replication and the 3' end of the polyhedron gene was prepared by gel isolation (fragment A). pIVEVSIgKp was digested to completion with PstI and KpnI to produce two fragments and the smaller fragment, which contained the polyhedron gene promoter and the polylinker was prepared by gel isolation (fragment B). Fragment A and B were then joined by DNA ligase to form the new plasmid pIVEVSIgKpNI which contains a partially deleted polyhedron gene into which a polylinker has been inserted and also contains a NotI site (replacing the destroyed EcoRI site) and a SfiI site which flank the polyhedron gene region.

pIVEPO

[0092] pIVEVSI gKpNI was digested to completion with EcoRI to linearize the plasmid and the 1340 bp EcoRI fragment from lambda-HEPOFL13 was inserted. Plasmids containing the EPO gene in the orientation such that the 5' end of the EPO gene is nearest to the polyhedron promoter and the 3' end of the polyhedron gene were identified by digestion with BglII. One of these plasmids in the orientation described above was designated pIVEPO.

Expression of EPO in Insect Cells

[0093] Large amounts of the pIVEPO plasmid were made by transforming the *E. coli* strain JM101-igi. The plasmid DNA was isolated by cleared lysate technique (Maniatis and Fritsch, Cold Spring Harbor Manual) and further purified by CsCl centrifugation. Wild-type Autographa californica polyhedrosis virus (AcNPV) strain L-1 DNA was prepared by phenol extraction of virus particles and subsequent CsCl purification of the viral DNA.

[0094] These two DNAs were then cotransfected into *Spodoptera frugiperda* cells IPLB-SF-21 (Vaughn et al., *In Vitro* Vol. B, pp. 213-17 (1977)) using the calcium phosphate transfection procedure (Potter and Miller, 1977). For each plate of cells being cotransfected,  $\mu$ g of wild-type AcNPV DNA and 10  $\mu$ g of pIVEPO were used. The plates were incubated at 27°C for 5 days. The supernatant was then harvested and EPO expression in the supernatant was confirmed by radioimmunoassay and by *in vitro* biological assay.

Example 15: Purification of EPO

[0095] COS-cell conditioned media (121) with EPO concentrations up to 200 $\mu$ g/litre was concentrated to 800ml using 10,000 molecular weight cutoff ultrafiltration membranes, such as a Millipore Pellican® fitted with 5 sq. ft. of membrane. Assays were performed by RIA as described in Example 6. The retentate from the ultrafiltration was dialyzed against 4ml of 10mM sodium phosphate buffered at pH7.0. The concentrated and dialyzed condition media contained 2.5mg of EPO in 380mg of total protein. The EPO solution was further concentrated to 186ml and the precipitated proteins were removed by centrifugation at 110,000 xg for 30 minutes.

[0096] The supernatant which contained EPO (2.0mg) was adjusted to pH5.5 with 50% acetic acid, allowed to stir at 4°C for 30 minutes and the precipitate removed by centrifugation at 13,000 xg for 30 minutes.

Carbon/Methyl Sapharose Chromatography

[0097] The supernatant from the centrifugation (20ml) containing 200 $\mu$ g of EPO (24mg total protein) was applied to a column packed with CM-Sephacrose (20ml) equilibrated in 10mM sodium acetate pH5.5, washed with 40ml of the same buffer. EPO which bound to the CM-Sephacrose was eluted with a 100ml gradient of NaCl(0-1) in 10mM sodium phosphate pH5.5. The fractions containing EPO (total of 50 $\mu$ g in 2mg of total proteins) were pooled and concentrated to 2ml using Amicon YM10 ultrafiltration membrane.

Reverse phase-HPLC

[0098] The concentrated fractions from CM-Sephacrose containing the EPO was further purified by reverse phase-HPLC using Vydac C-4 column. The EPO was applied onto the column equilibrated in 10% solvent B (Solvent A was 0.1% CF<sub>3</sub>CO<sub>2</sub>H in water; solvent B was 0.1% CF<sub>3</sub>CO<sub>2</sub>H in CF<sub>3</sub>CN) at flow rate of 1ml/min. The column was washed with 10 $\mu$ B for 10 minutes and the EPO was eluted with linear gradient of B (10-70% in 60 minutes). The fractions containing EPO were pooled (~40 $\mu$ g of EPO in 120 $\mu$ g of total proteins) and lyophilized. The lyophilized EPO was reconstituted in 0.1M Tris-HCl at pH7.5 containing 0.15M NaCl and rechromatographed on the reverse phase HPLC. The fractions containing the EPO were pooled and analyzed by SDS-polyacrylamide (10%) gel electrophoresis (Lameli, U.K., *Nature*). The pooled fractions of EPO contained 15.5 $\mu$ g of EPO in 25 $\mu$ g of total protein.

REFERENCES

[0099]

- 1) Jacobson, L. O., Goldwasser, E., Fried, W., and Plzak, L. F., *Trans. Assoc. Am. Physicians* TO-305-317 (1957).
- 2) Krantz, S. B. and Jacobson, L. O., *Chicago: University of Chicago Press* 1970, pp. 28-31.
- 3) Hammond, D. and Winnick, S., *Ann. N.Y. Acad. Sci.* 230:219-227 (1974).
- 4) Sherwood, J. B. and Goldwasser, E., *Endocrinology* 103:665-670 (1978).
- 5) Fried, W., *Blood* 40:671-677 (1972).
- 6) Fisher, J. J., *Lab. and Clin. Med.* 93:695-699 (1979).
- 7) Naughton, B. A., Kaplan, S. M., Roy, M., Burdowski, A. J., Gordon, A. S., and Pillero, S. J., *Science* 196:301-302.
- 8) Lucarelli, G. P., Howard, D., and Stohman, F., *J. Clin. Invest.* 43:2195-2203 (1964).
- 9) Zanjani, E. D., Foster, J., Burlington, H., Mann, L. I., and Wasserman, L. R., *J. Lab. Clin. Med.* 88:640-644 (1977).
- 10) Krantz, S. B., Gallien-Larigue, O., and Goldwasser, E., *J. Biol. Chem.* 238:4085-4090 (1963).
- 11) Dunn, C. D., Jarvis, J. H. and Greenman, J. M., *Exp. Hematol.* 3:65-78 (1975).
- 12) Krystal, G., *Exp. Hematol.* 11:649-660 (1983)



- 13) Iscove, N.N. and Guilbert, L.J., M.J. Murphy, Jr. (Ed.) New York: Springer-Verlag, pp. 3-7 (1978).
- 14) Goldwasser, E., *IGN UCLA Symposium*, Control of Cellular Division and Development, A. R. Liss, Inc., pp. 487-494 (1981)
- 15) Cline, M. J. and Golde, D. W. *Nature* 277:177-181 (1979)
- 16) Melnick, D., Johnson, G. R., and Burgess, A. W. *Blood* 55:138- (1980)
- 17) Krane, N. *Henry Ford Hosp. Med. J.* 31:177-181 (1983)
- 18) Eschbach, J., Madenovic, J., Garcia, J., Wahl, P., and Adamson, J. J. *Clin. Invest.* 74:434-441 (1984)
- 19) Anagnostou, A., Barone, J., Vedo, A., and Fried, W. *Br. J. Haematol.* 37:85-91 (1977)
- 20) Miyake, T., Kung, C., and Goldwasser, E. *J. Biol. Chem.* 252:5556-5564 (1977)
- 21) Yanagawa, S., Hirade, K., Ohnoda, H., Sasaki, R., Chiba, H., Veda, M., and Goto, M. *J. Biol. Chem.* 259:2707-2710 (1984)
- 22) Lawn, R. M., Fritsch, E. F., Parker, R. C., Blake, G., and Maniatis, T. *Cell* 15:1157- (1978)
- 23) Sanger, F., Nicklen, S., and Coulson, A. R. *Proc. Natl. Acad. Sci. U.S.A.* 74:5463- (1977)
- 24) Zanjani, E. D., Acconzo, J. L., McGlave, P. B., Banisadr, M., and Ash, R. C. *J. Clin. Invest.* 87:1183- (1981)
- 25) Toole, J. J., Knopf, J. L., Wozney, J. M., Sultman, L. A., Buecker, J. L., Pittman, D. D., Kaufman, R. J., Brown, E., Shoemaker, C., Orr, E. C., Amphlett, G. W., Foster, W. B., Coo, M. L., Knutson, G. J., Fass, D. N., and Hewick, R. M. *Nature in Press*
- 26) Goldwasser, E. *Blood Suppl.* 1, 58, xlii (abstr) (1981)
- 27) Sue, J. M. and Sytkowski, A. J. *Proc. Natl. Acad. Sci. U.S.A.* 80:3651-3655 (1983)
- 28) Bersch, N. and Golda, D. W., in *Vitro Aspects of Erythropoiesis*, M. J. Murphy (Ed.) New York: Springer-Verlag (1978)
- 30) Coates, P. M. and Bingham, D. R. *Nature* 191:1065- (1961)
- 31) Goldwasser, E. and Gross, M. *Methods in Enzymol.* 37:109-121 (1975)
- 32) Nabeshima, Y., Fujii-Kuriyama, Y., Muramatsu, M., and Ogata, K. *Nature* 308:333-338 (1984)
- 33) Young, R. A., Hagenbuchle, O., and Schibler, U. *Cell* 23:451-558 (1981)
- 34) Medford, R. M., Nguyen, H. T., Destree, A. T., Summers, E. and Nadal-Ginard, B. *Cell* 38:409-421 (1984)
- 35) Ziff, E. B. *Nature* 287:481-489 (1980)
- 36) Early, P. *Cell* 20:313-318 (1980)
- 37) Sytkowski, A. *Bio. Bio. Res. Comm.* 96:143-149 (1980)
- 38) Murphy, M. and Miyake, T. *Acta Haematol.* 46:1380-1386 (1983)
- 39) Wagh, P. V. and Bahl, O. P. *CRC Critical Reviews in Biochemistry* 307-377 (1981)
- 40) Wang, F. F., Kung, C. K. H., and Goldwasser, E. *Exp. Proc. Fed. Am. Soc. Exp. Biol.* 42:1872 (abstr) (1983)
- 41) Lowy, P., Neighley, G. and Borscock, H. *Nature* 185:102-103 (1980)
- 42) VanLenten, L. and Ashwell, G. *J. Biol. Chem.* 247:4633-4640 (1972)
- 43) Lee-Huang, S. *Proc. Natl. Acad. Sci. U.S.A.* 81:2708-2712 (1984)
- 44) Fyhrquist, F., Rosenior, K., Gronhagen-Riska, C., Hurling, L. and Tikkanen, I. *Nature* 308:649-662 (1984)
- 45) Ohkubo, H., Kageyama, R., Vijnara, M., Hirose, T., Inayama, S., and Nakanishi, S. *Proc. Natl. Acad. Sci. U.S.A.* 80:2198-2200 (1983)
- 46) Suggs, S. V., Wallace, R. B., Hirose, T., Kawashima, E. H. and Itakura, K. *Proc. Natl. Acad. Sci. U.S.A.* 78:6613-6617 (1981)
- 47) Woo, S. L. C., Dugaczkyk, A., Tsai, M. -J., Lai, E. C., Catterall, J. F. and O'Walley, B. W. *Proc. Natl. Acad. Sci. U.S.A.* 75:3688- (1978)
- 48) Melchior, W. B. and VonHippel, P. H. *Proc. Natl. Acad. Sci. U.S.A.* 70:298-302 (1973)
- 49) Orsz, J. M. and Waimis, J. G. *Blood* 16:1183-1199 (1977)
- 50) Anderson, S. and Kingston, I. B. *Proc. Natl. Acad. Sci. U.S.A.* 80:6836-6842 (1983)
- 51) Ulrich, A., Coussens, L., Hayflick, J. S., Dull, T. J., Gray, A., Tam, A. W., Lee, J., Yarden, Y., Libermann, T. A., Schlessinger, J., Downward, J., Mayes, E. L. V., Whittle, H., Waterfield, M. D. and Seeburg, P. H. *Nature* 308:418-425 (1984)
- 52) Fisher, J. *Proc. Soc. Exptl. Biol. and Med.* 173:289-305 (1983)
- 53) Kozak, M. *Nuc. Acid Res.* 12:857-872 (1984)
- 54) Benton, W. D. and Davis, R. W. *Science* 196:180-182 (1977)
- 55) Sherwood, J. B. and Goldwasser, E. *Blood* 54:885-893 (1979)
- 56) Derman, E., Krauter, K., Weiling, L., Weinberger, C., Ray, M., and Darnell, J. T., *Cell* 23:731- (1981)
- 57) Gluzman, Y., *Cell* 23:175-182 (1981)
- 58) Hewick, R. M., Hunkapiller, M. E., Hood, L. E., and Dreyer, W. J. *J. Biol. Chem.* 256:7990-7997 (1981)
- 59) Towbin, H., Staehelin, T., and Gordon, J., *Proc. Natl. Acad. Sci.* 76:4380- (1979)
- 60) Carnot, P., DeFlandre, C. C. B. *Acad. Sci. Paris* 143:432- (1980)

## Claims

1. A method for the production of human erythropoietin comprising culturing in a suitable medium eukaryotic host cells containing the DNA sequence as shown in Table 3 from the sequence ATG encoding initial Met through AGA encoding the terminal Arg operatively linked to an expression control sequence, and separating the erythropoietin so produced from the cells and the medium.
2. A method of claim 1, wherein the culture medium contains fetal serum.
3. A method of one of the preceding claims, wherein the host cells are mammalian cells.
4. A method of claim 3, wherein the mammalian host cells are COS, CHO, C127 or 3T3 cells.
5. A method of claim 3, wherein the mammalian cells are 3T3 cells.
6. A method of claim 3, wherein the mammalian cells are Chinese hamster ovary (CHO) cells.
7. A method of claim 3, wherein said DNA sequence is contained in a vector also containing bovine papilloma virus DNA.

## Patentansprüche

1. Verfahren zur Herstellung von humanem Erythropoietin, umfassend das Kultivieren von eukaryontischen Wirtszellen in einem geeigneten Medium, die die DNA Sequenz, wie in Tabelle 3 gezeigt, von der Sequenz ATG, kodierend für ein anfängliches Met, bis AGA, kodierend für das terminale Arg enthalten, welche operativ mit einer Expressionskontrollsequenz verknüpft ist, und das Abtrennen des so erzeugten Erythropoietins von den Zellen und dem Medium.
2. Verfahren nach Anspruch 1, worin das Kulturmedium fötales Serum enthält.
3. Verfahren nach einem der vorhergehenden Ansprüche, worin die Wirtszellen Säugerzellen sind.
4. Verfahren nach Anspruch 3, worin die Säuger-Wirtszellen COS, CHO, C127 oder 3T3 Zellen sind.
5. Verfahren nach Anspruch 3, worin die Säugerzellen 3T3 Zellen sind.
6. Verfahren nach Anspruch 3, worin die Säugerzellen Chinesischer-Hamster-Ovarien (CHO) Zellen sind.
7. Verfahren nach Anspruch 3, worin die DNA-Sequenz in einem Vektor enthalten ist, der auch Bovine Papilloma Virus DNA enthält.

## Revendications

1. Procédé de production d'érythropoïétine humaine comprenant la culture dans un milieu approprié de cellules hôtes eucaryotes contenant la séquence d'ADN telle que représentée dans le tableau 3 de la séquence ATG codant la Met initiale à AGA codant la Arg terminale liée de manière active à une séquence de contrôle d'expression, et la séparation de l'érythropoïétine ainsi produite des cellules et du milieu.
2. Procédé selon la revendication 1 dans lequel le milieu de culture contient du sérum fœtal.
3. Procédé selon l'une des revendications précédentes dans lequel les cellules hôtes sont des cellules de mammifère.
4. Procédé selon la revendication 3 dans lequel les cellules hôtes de mammifère sont des cellules COS, CHO, C127 ou 3T3.
5. Procédé selon la revendication 3 dans lequel les cellules de mammifère sont des cellules 3T3.

6. Procédé selon la revendication 3 dans lequel les cellules de mammitaire sont des cellules d'ovaire de hamster chinois (CHO).
7. Procédé selon la revendication 3 dans lequel ladite séquence d'ADN est contenue dans un vecteur contenant aussi de l'ADN de papillomavirus bovin.

ADULT LIVER  
FETAL LIVER



FIG. 1

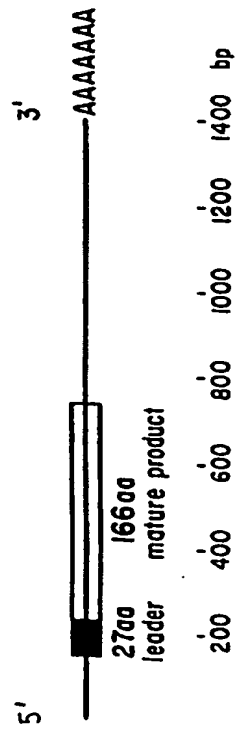
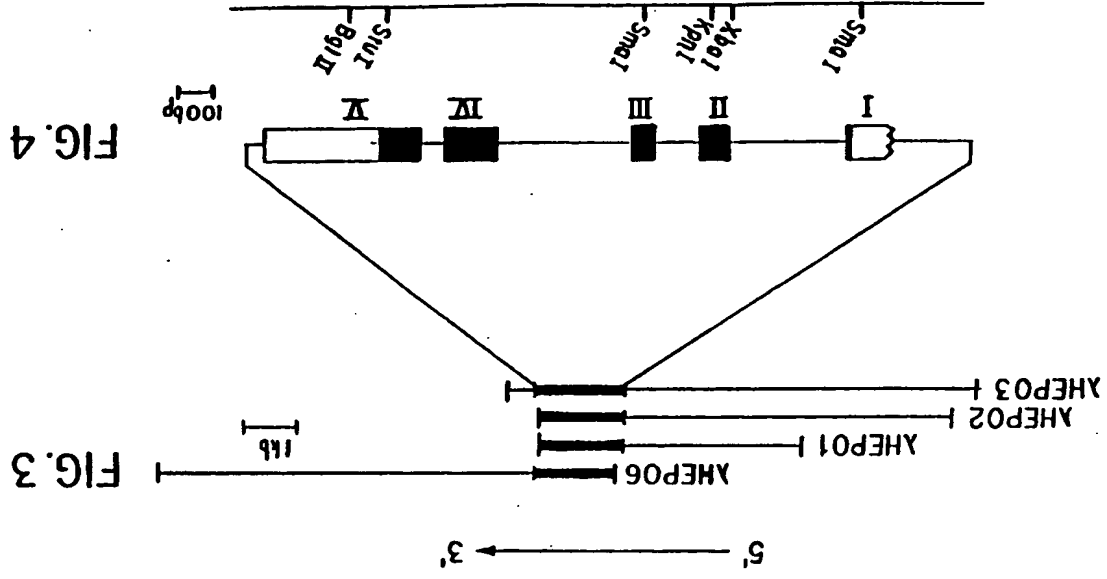


FIG. 2



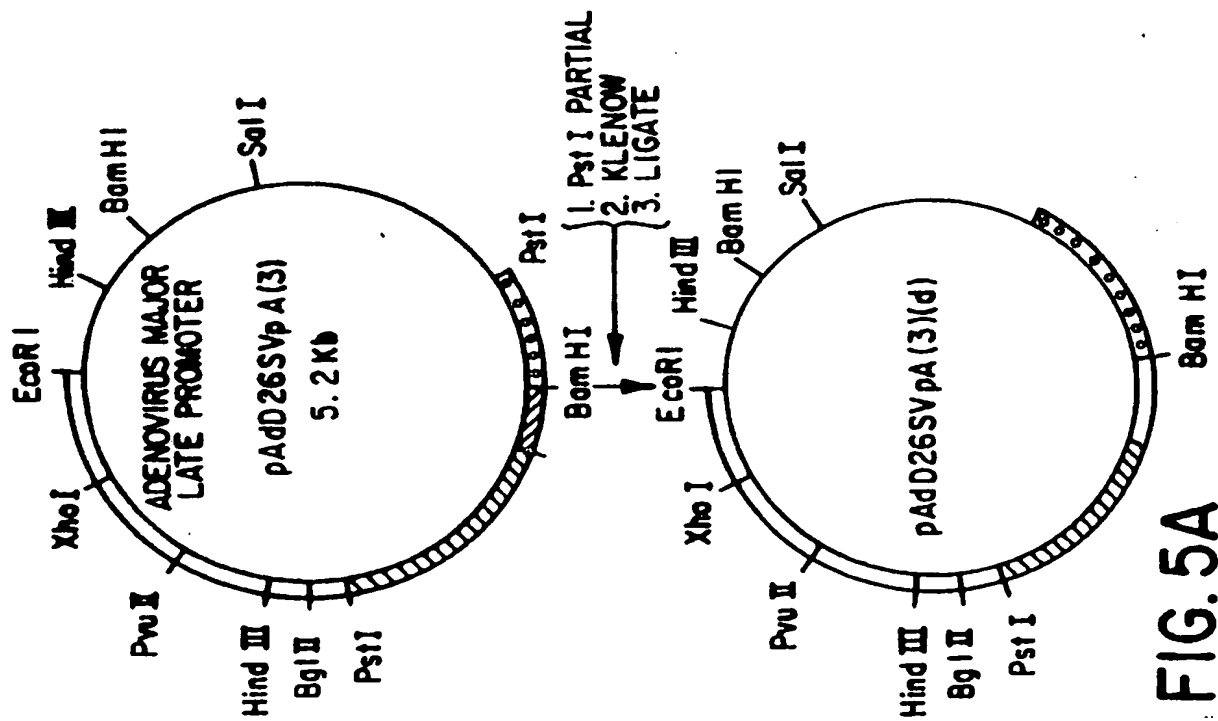


FIG. 5A

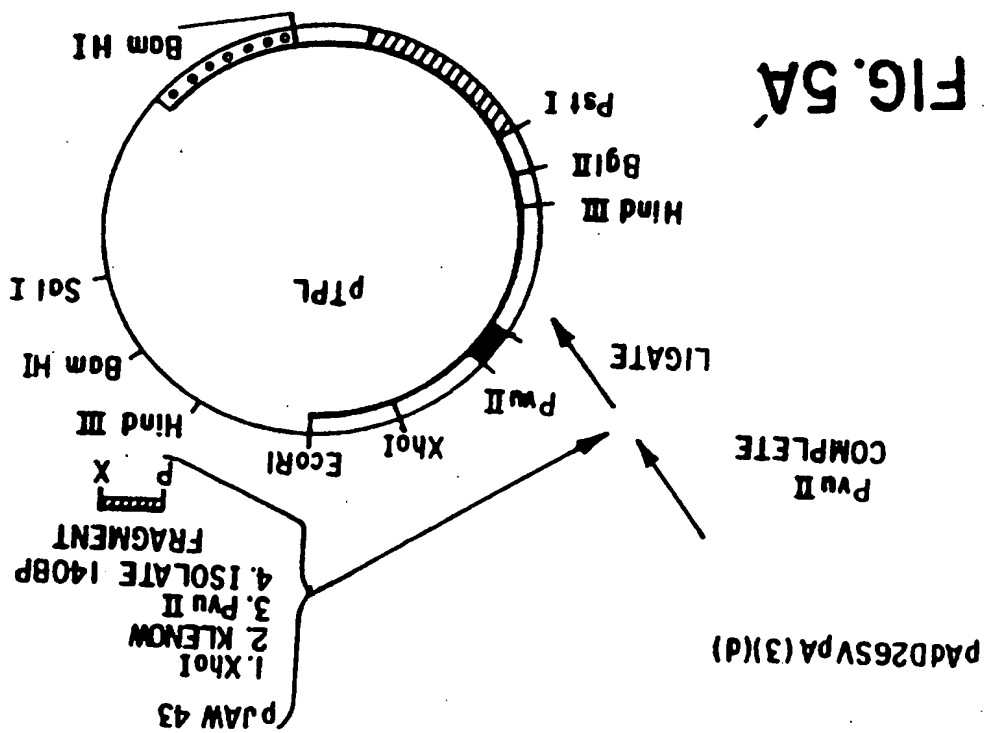


FIG. 5A

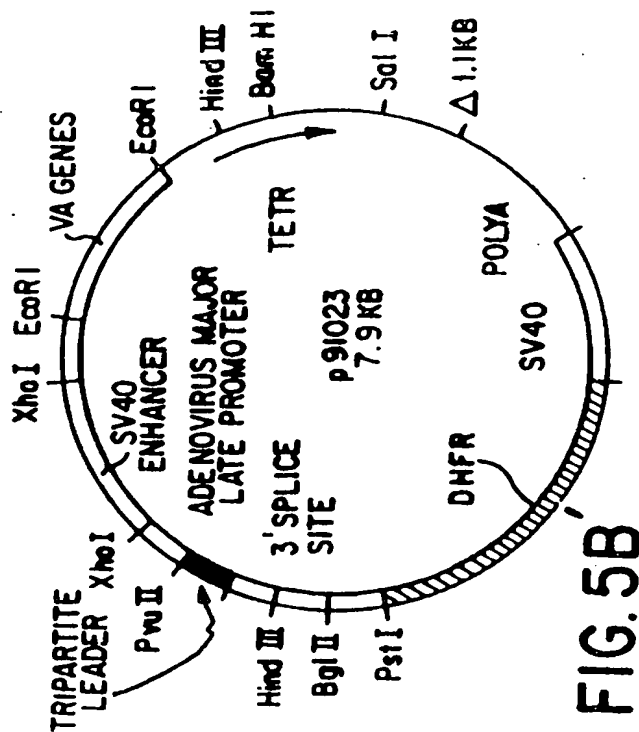
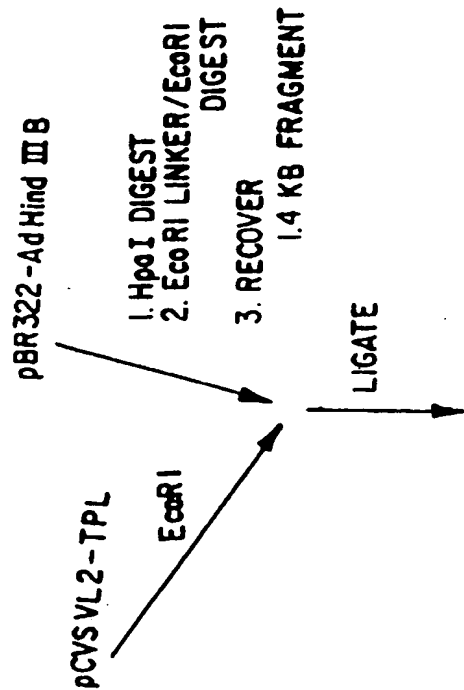


FIG. 5B

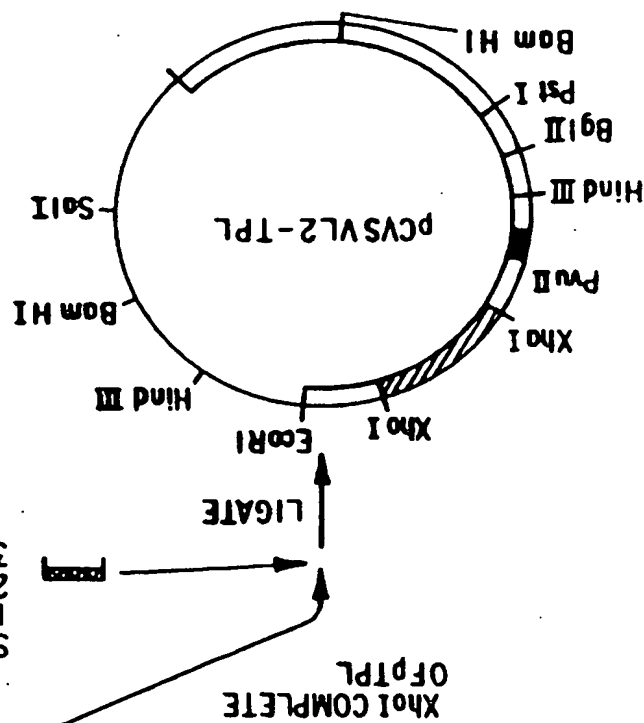
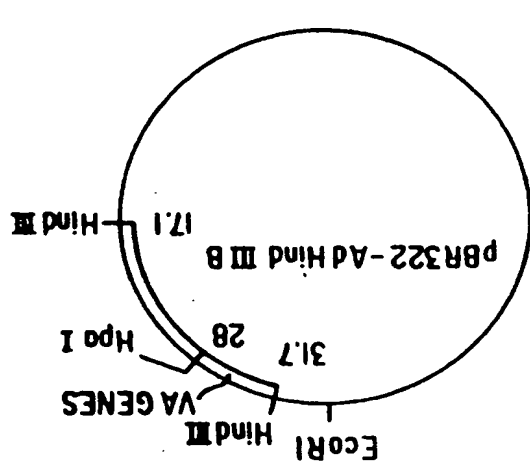


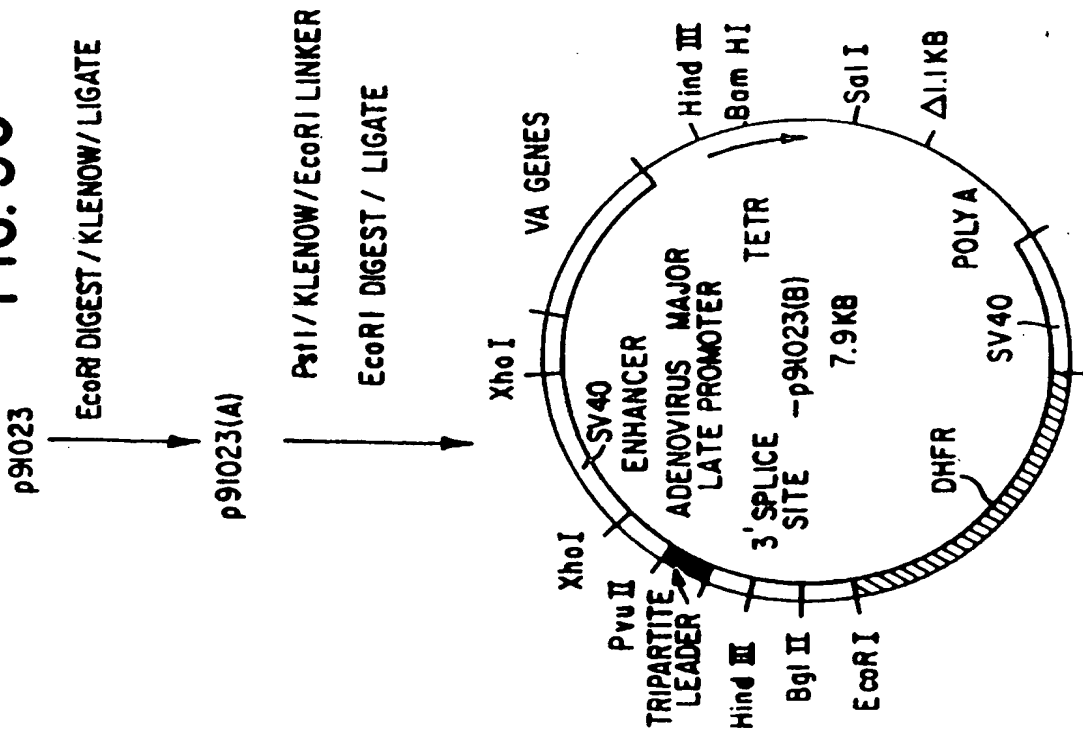
FIG. 5B

SV40 DNA  
1. Ayo II DIGEST  
2. MhoI LINKER/XhoI DIGEST  
3. RECOVER D FRAGMENT

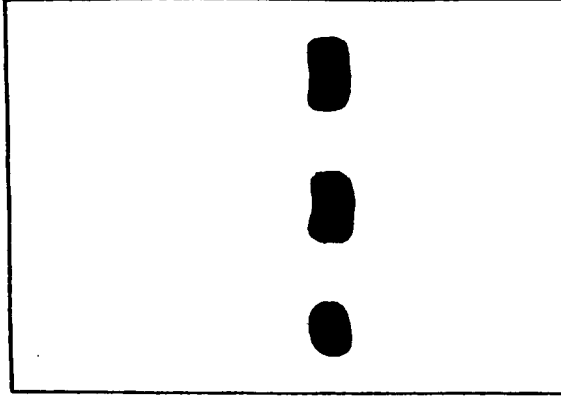
LIGATE

XhoI COMPLETE  
OF TPL

FIG. 5C



NATURAL EPO  
RECOMBINANT EPO  
125 I NATURAL EPO



68000d  
45000d

FIG. 6

FIG. 8

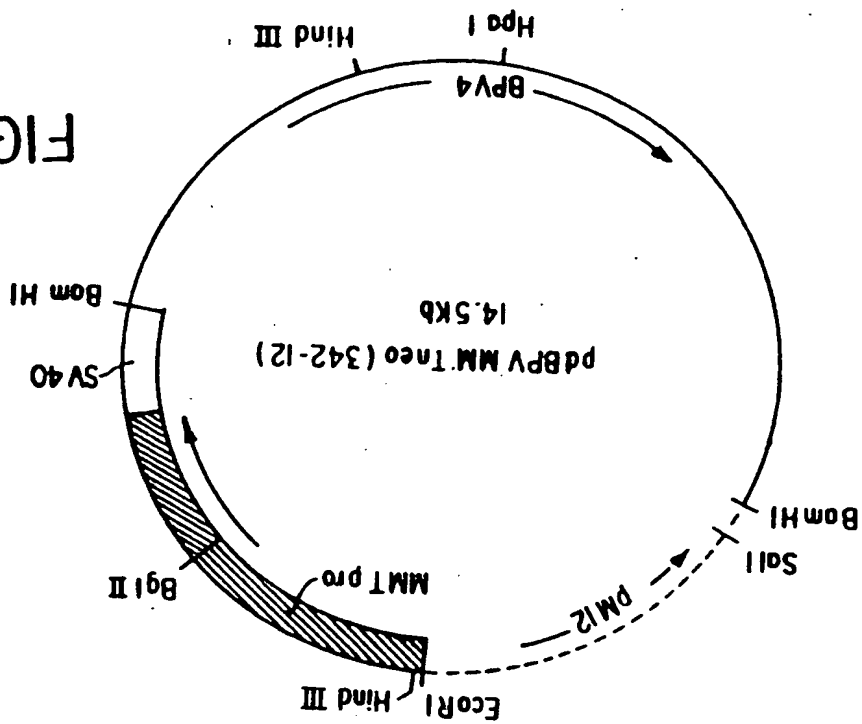


FIG. 7

